The features of soil aggregation and its eco-environmental effects under different subalpine forests on the east slope of Gongga Mountain, China

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Abstract: Structural properties of forest soils have important hydro-ecological function and can influence the soil water-physical characters and soil erosion. The experimental soil samples were obtained in surface horizon (0-10 cm) from different subalpine forest types on east slope of Gongga Mountain in the upriver area of Yangtze River China in May 2002. The soil bulk density, porosity, stable infiltration rate, aggregate distribution and particle-size distribution were analyzed by the routine methods in room, and the features and effects on eco-environment of soil aggregation were studied. The results showed that the structure of soil under mixed mature forest is in the best condition and can clearly enhance the eco-environmental function of soil, and the soil structure under the clear-cutting forest is the worst, the others are ranked between them. The study results can offer a basic guidance for the eco-environmental construction in the upper reaches of Yangtze River.

Keywords: Soil aggregation; Eco-environmental effects; Subalpine forest; Gongga Mountain, China

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Introduction

Many research results have indicated that forest soils are one of important factors of influencing the forest hydro-ecological function (Cognard-plancq *et al.* 2001; Zhao *et al.* 2001; Gao 2000). Soil structure is one of important soil properties, and soil aggregates and its stability have a significant influence for soil physical behavior. In particular, water infiltration, water-holding, and soil erosion depend strongly on it (Boix 1997; Bissonnais 1996). The upriver eco-environment of Yangtze River in China has a significant function to the whole country. The Gongga Mountain, with the highest peak of 7 556 m a.s.l, is located in the southeast of Tibetan Plateau and is the water resource of Daduhe River that is one of distributaries of upriver Yangtze River. This paper mainly studied the soil pedogenetic classification and geographical distribution of Gongga Mountain. The structural properties and eco-environmental effects of soils under different forest types on east slope of Gongga Mountain were discussed, which will offer a basic guidance for forestry breeding and management and the improvement of the upriver eco-environment of Yangtze River.

Site description and methods

The study was conducted in Hailuogou of east slope of Gongga Mountain, with an altitude of 2 600~3 600 m. Annual average temperature is 4.29℃, and annual precipitation is 1 980 mm. Parent materials of soils are mainly residual-slope deposits of granites and glacial tills. Main components of vegetation are *Abies fabri* and *Rhododendron*. The natural conditions of typical soil profiles were shown in another paper (Zhang *et al.* 2002).

The soil samples were collected from A horizons (0-10 cm) of soils by cylinder cutting (50 mm in inner diameter and 50 mm in height) under different forest types. The mass water content, bulk density, infiltration and porosity of samples were measured by routine methods.

The samples were taken by aluminium boxes and dried at room temperature (25℃) to analyze the aggregate and particle of soils. Dry soil samples are dry-wet sieved handed by a nest of sieves with mesh openings of 10 mm, 5 mm, 3 mm, 2 mm, 1 mm, 0.5 mm, 0.25 mm for measuring the aggregate size distribution. To evaluate and compare the difference of structure property of soils, the Mean Weight-Diameter (MWD), Fractal Dimension (FD) are calculated.

Results and analysis

Aggregate component and evaluation

The aggregate components of soil samples were obtained by dry-wet sieving handed, and the MWD_d, MWD_w, FD_d and FD_w were calculated. The results were shown in Table 1.

Mean Weight-Diameter (MWD) was proposed by C.H.M. van Bavel in 1949 to evaluate soil aggregate, and the soil structure is in better condition when MWD is larger. MWD is defined as follows:

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$$MWD = \sum_{i=1}^{n} X_i \times W_i \quad (1)$$

In equation (1), MWD is defined as the Mean Weight-Diameter of aggregate (mm), X_i is average diameter within a range of diameters of aggregate, W_i is the percent of the aggregate weight within a range of diameters.

Fractal dimension (FD) was calculated by the model which was presented by Yang P. L. *et al.* (1993), and the soil structure is in better condition when FD is smaller. FD is defined as follows:

$$D = 3 - \lg(W_i / W_0) / \lg(d_{iave} / d_{max}) \quad (2)$$

In equation (2), D is the Fractal dimension of aggregate. W_i is cumulated weight of aggregates with diameter less than d_i, W_0 is the total weight of aggregates, d_{iave} is average diameter of d_i and d_{i+1}, d_{max} is the diameter of the largest aggregate.

While the MWDds ranged from 1.60 to 5.26, the largeness sequence was mixed-mature forest (V), middle-aged forest (VI), over-mature forest (I), secondary forest (II), and the forest with clear cutting (III) (Shown in Table 2). The MWDws changed between 2.83-1.03, and the sequence was V>VI>II>I>III. The FDds were changed between 2.084~2.706, and the sequence was V<VI<II<I<III. The FDws were changed between 2.532-2.709, and the sequence was V<II<VI<I<III. These sequences showed that the structure of soil under mixed-mature forest (V), with four indexes in the first place, was in the best condition, the structure of soil under the clear-cutting forest (III) was in the worst condition, and the others (II, VI, I) were ranked between them.

Table 1. Aggregate component (%) and MWD (mm), FD of soils (0-10 cm)

Forest type	Aggregate component /%								MWD /mm	FD
	>10	10~5	5~3	3~2	2~1	1~0.5	0.5~0.25	<0.25		
I -a	3.84	17.45	11.66	6.14	11.06	19.64	11.96	18.26	2.72	2.586
-b		13.01	10.05	7.48	11.52	14.58	6.40	36.96	1.64	2.799
II -a	2.61	13.45	11.94	7.21	9.86	26.93	12.37	15.64	2.36	2.552
-b		11.96	8.99	14.26	17.66	18.71	4.32	24.09	1.80	2.594
III -a	2.65	4.91	8.55	7.52	9.20	21.41	17.02	28.75	1.60	2.706
-b		3.36	5.85	3.92	14.56	24.91	5.79	41.62	1.03	2.709
V -a	18.23	27.10	16.98	9.42	10.82	9.85	2.48	5.12	5.03	2.084
-b		32.07	21.76	4.30	5.07	15.51	15.57	5.72	2.85	2.532
VI -a	6.02	13.04	46.34	8.22	8.43	10.31	4.65	3.00	3.87	2.097
-b		19.13	6.44	15.90	13.91	9.96	10.30	24.35	1.99	2.757

Note: -a and –b are dry, wet sieved aggregate-size distribution, respectively.

Characteristics of aggregation

The characteristics of aggregation, which are based on soil micro-aggregate-size distribution and soil particle-size distribution, are applied widely in the studies of soil aggregation potential and anti-erodibility. They are defined as follows (Shen *et al.* 2000):

Aggregation status = micro-aggregates (>0.05mm)−soil particle (>0.05mm)

Aggregation degree=

$$\frac{aggregation - status}{microaggregates(>0.05mm)} \times 100\%$$

Dispersion ratio=

$$\frac{microaggregates(<0.05mm)}{particles(<0.05mm)} \times 100\%$$

Dispersive coefficient=

$$\frac{microaggregates(<0.001mm)}{particles(<0.001mm)} \times 100\%$$

Structure coefficient=

$$1 - \frac{microaggregates(<0.001mm)}{particles(<0.001mm)}$$

Structure holding ratio=

$$\frac{microaggregates(>0.01mm) - particles(>0.01mm)}{microaggregates(>0.01mm)} \times 100\%$$

Structure ped break ratio=

$$\frac{aggregates(drysieving > 0.25mm) - aggregates(wetsieving > 0.25mm)}{aggregates(drysieving > 0.25mm)}$$

From the results shown in Table 2, we can see that the soils under mixed-mature forest (V), over-mature forest (I) and middle-aged forest (VI) were best in most of indexes, while the soils under clear-cutting forest (III) and secondary forest (II) were in the worst conditions.

Eco-environment of aggregation characteristics

Control of soil erosion

The stability of soil aggregate is an important factor of endogenic agency of soil erosion, and many methods have been widely used to measure the stability of soil aggregate around the world since the late 1930s. Le B.Y. summarized those methods and gave a unified methodological framework for the measurement of aggregate stability (Le 1996). In this framework, the aggregate is at stable and very stable level when the MWD are 1.3~2.0 and >2.0, respectively.

Other researchers used the structure coefficient and the dispersive coefficient (Wang *et al.* 1994), and the percent of water stable aggregates (>0.25 mm) (Guo *et al.* 1992) to express soil antierodibility.

In this paper, the soils aggregate MWD_w are separately 2.83 for forest type V, 1.80 for II, 1.71 for VI, 1.43 for I, and 1.03 for III. These indicate that the aggregates of soils are very stable (V), stable (II, VI, I), and medium stable (III), respectively, which play an important role in soil anti-erodibility, and the values of water stable aggregates (>0.25 mm) of soils were all larger than 57%.

Table 2. The characteristics of soil aggregation

Soil type	Water stable aggregates (>0.25mm) /%	Aggregation status /%	Aggregation degree /%	Structure coefficient /%	Structure holding ratio /%	Dispersion ratio /%	Dispersive coefficient /%	Structure ped break ratio /%
I	63.04	22 43	22.53	99.43	13.97	1.92	0.57	22.88
II	75.91	19.26	19.32	99.39	7.79	1.58	0.61	10.02
III	58.38	15.65	15.71	99.42	9.72	2.37	0.58	18.06
V	94.28	20.01	20.10	99.49	12.96	2.10	0 51	0.63
VI	75.65	25.19	25.25	99.55	19.36	0.87	0.45	22 01

Water infiltration

Water infiltration is an important factor for soil hydrologic cycle. More precipitation were converted into underground water and less surface runoff formed when water infiltration rates are larger. The infiltration rates of saturated soil samples were shown in Fig.1.

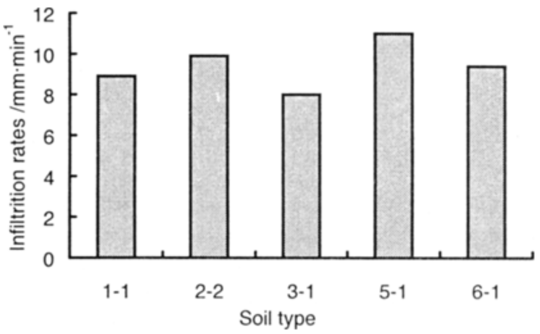

Fig. 1 Soil infiltration rates

The infiltration rates of soil under the mixed-mature forest (V(5-1), 11.0 $mm \cdot min^{-1}$) is the biggest, and followed by secondary forest (II(2-2), 9.9 $mm \cdot min^{-1}$), middle-aged forest (VI(6-1), 9.4 $mm \cdot min^{-1}$), over mature forest (I(1-1), 8.9 $mm \cdot min^{-1}$), and that of slash soil (III(3-1), 8.0 $mm \cdot min^{-1}$) is the smallest. This means that the forest soils have a better ability of water infiltration. The correlation coefficients of MWD_d, MWD_w, FD_d, and Fd_w with and stable infiltration rates are 0.838, 0.974, -0.726, -0.936 ($n=5$, $r_{0.01(n-2)}=0.959$, $r_{0.05(n-3)}=0.878$), respectively, which imply that soil structural properties make a strong influence on water stable infiltration rate.

Preliminary conclusions

The above-mentioned indexes, revealing soil structure consistency, play very important roles in studying soil structure and the influences of the soil on eco-environment. The soil structure has a great difference under different forest types. The best soil is under mixed-mature forest (V), the worst is slash soil (III), and others ranked between them. The stable communities structure and the completely tangled botanic roots under mixed-mature forest can protect aggregates from breaking-down by water-drops and increase water-stable aggregates and pores.

Mature and over-mature forests cover extensively on Gongga Mountain area, thus soil structure is in better conditions generally and the forest-soil system can improve eco-environment greatly. If species diversity is increased and the maturation accelerated, the soil structure would benefit the hydro-ecological function of forest-soil system and eco-environmental development in upper reach of Yangtze River.

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